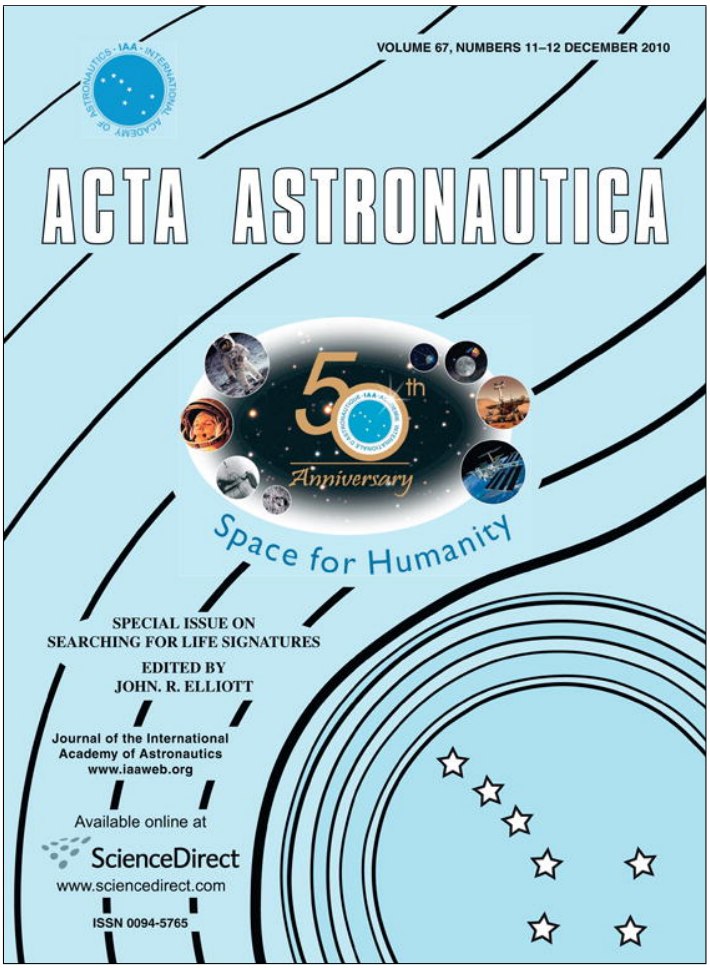

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SETI meets a social intelligence: Dolphins as a model for real-time interaction and communication with a sentient species

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ABSTRACT

In the past SETI has focused on the reception and deciphering of radio signals from potential remote civilizations. It is conceivable that real-time contact and interaction with a social intelligence may occur in the future. A serious look at the development of relationship, and deciphering of communication signals within and between a non-terrestrial, non-primate sentient species is relevant. Since 1985 a resident community of free-ranging Atlantic spotted dolphins has been observed regularly in the Bahamas. Life history, relationships, regular interspecific interactions with bottlenose dolphins, and multi-modal underwater communication signals have been documented. Dolphins display social communication signals modified for water, their body types, and sensory systems. Like anthropologists, human researchers engage in benign observation in the water and interact with these dolphins to develop rapport and trust. Many individual dolphins have been known for over 20 years. Learning the culturally appropriate etiquette has been important in the relationship with this alien society. To engage humans in interaction the dolphins often initiate spontaneous displays, mimicry, imitation, and synchrony. These elements may be emergent/universal features of one intelligent species contacting another for the intention of initiating interaction. This should be a consideration for real-time contact and interaction for future SETI work.

1. Introduction

We know from previous work that dolphins have both behavioral and cognitive flexibility [1,2]. Dolphins understand word order (syntax), word meaning (semantics) abstract thought, and show self-awareness [3,4]. These experiments have been in the context of a one-way comprehensive situation. Even with these human constraints, dolphins perform adeptly at adapting to our communication system. Next to humans, dolphins have the highest encephalization quotient (EQ), a measure of brain to body ratio [5]. Like primates, elephants, and some species of birds, dolphins have complex social structure, communication signals, and social politics thought to be factors for driving the evolution of convergent intelligence. Looking at non-human animal societies on earth may help us understand different types of intelligence and develop models to interact with an alien society outside our own planet. But how do we recognize non-primate, non-terrestrial intelligence? How do we work with real-time interactions and etiquette with a non-familiar intelligence? Are there emergent qualities of interactions that can guide us? Although cetaceans, specifically dolphins, are known for their highly developed acoustic abilities, dolphins are mammals with other senses including tactile, vision, and taste. We would expect dolphins to utilize their full capacities of communication using all systems available. Past studies have focused on their acoustic communication, but even in the analysis of complex human language, context and information are distributed and interactive [6,7], and the interplay of

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multi-modal signals and social dynamics is the essence of complex information. Transmission directions and types of learning have also been reviewed [8] to show that multi-generational, peer to peer, as well as mother/calf learning may be prevalent in dolphin society.

Besides having features in common with both human societies and non-human primate societies (complex communication, social structure, and politics), dolphins have sensory systems that both overlap humans and lie outside the human perception. Some parts of dolphin communication have been well studied, including their use of the signature whistle [9,10]. Signature whistles and their referential use probably represent some rudimentary referential, or word-specific, communication signals similar to those described for other species [11]. Dolphins also have a graded component [12] of their acoustics, including other types of sounds such as burst-pulsed vocalizations and echolocation trains, used both for navigation and social behavior [13]. Referential and graded communication need not be mutually exclusive and may represent the most efficient use of the communication channels of dolphins. Dolphins may have their own, unique system of utilizing pertinent information with a hydrodynamic form [14].

We have known for some time that dolphin acoustic signals are directional. Historically, the acquisition of acoustic signals in both the wild and captivity has been done primarily without the orientation of the animal in mind or the directional abilities of the hydrophones. Therefore, it may be that partial signals, and breaks in time of signals may be an artifact of the dolphin's orientation. Recent work on the broadband acoustic signals of dolphins shows both directional importance [15] and the extensive range of social signals in the ultrasonic range (140 kHz+). This speaks of the need to build a broadband library of their sounds, including directionality-acquired sounds that may change our categorization of signals to more closely represent the dolphin's repertoire. It may also be fruitful to apply more advanced techniques, such as the KLT [16] to broadband signals to better decode information available in these frequency bands.

This paper describes a framework for long-term observations on a free-ranging community of dolphins that live in the wild, and whom have been the subjects of observation as well as interaction with humans for over 20 years. Specifically this paper addresses experimental two-way communication between humans and dolphins. It is hoped that such observations can help us understand not only a non-human society in their own right, but will illuminate the ethics, etiquette, and emergent features of bridging the gap with another sentient species.

2. Field site and methodology

In the Bahamas, a resident group of Atlantic spotted dolphins (*Stenella frontalis*) have been behaviorally observed underwater since 1985. Life history [17] correlations with sound and behavior [18], and interspecific interactions [19] have been described. Because of the clarity of the water and the regular access to the 220 resident individuals, this field site provides a unique opportunity to observe complex behavior in the wild.

Primary data include communication signals (acoustic and postural) from underwater videotapes of individuals of known age and gender interacting with one another. These measurable behaviors constitute the "media" that may flow between individuals. Distributed cognition suggests that cognition occurs not just within an individual mind, but also between individuals [20,21,6]. Categorical issues for many species are still an issue and yet to be determined [22,23]. Because interactions between individuals can be recorded (e.g., behavior), they become measurable phenomena, unlike mental states and concepts like "intention" that are difficult to assess.

3. Study site—Bahamas

Since 1985, Atlantic spotted dolphins have been observed every summer for approximately 100 d on the NW Little Bahama Bank. This is an area of shallow water, ranging approximately 6–16 m in depth, 450 km^2 in size, which lies north of Grand Bahama Island. Underwater visibility averages 30 m. Observations are conducted using a 20-m motor-powered catamaran. The life history, reproductive activity, association patterns, and underwater sound and behavior of these resident dolphins have been documented for 24 years, spanning three generations.

Researchers regularly enter the water to obtain underwater video and simultaneous sound using various cameras (Sony TRV PC110, Yashica KXV1u Hi8mm) with attached hydrophones. Sampling includes ad libitum, focal, and behavioral events [24]. All dolphins have been identified by sex through underwater visual observation of the genital area. Other data recorded include date, time, location, association of other individuals, and environmental information. Video information is logged and reviewed every evening on board the research vessel. A long-term data set of audio and visual information has been archived since 1985 and is accessible for detailed analysis based on individuals (220 spotted dolphins, 200 bottlenose dolphins), age classes, and behavior categories (aggression, courtship, etc.).

Many species already utilize the calls and signals of other species to their advantage [25]. McConnell [26] describes specific communication patterns between domestic dogs and their owners. Dolphins in the wild have a history of interactive, and sometimes cooperative, arrangements with humans [27]. Atlantic spotted dolphins in this community interact with a second species of delphinid, bottlenose dolphins (*Tursiops truncatus*) on a regular and intimate basis [19]. This interaction, partnered with spontaneous interactions with human researchers over the years, prompted consideration of exploring two-way communication. Although the primary goal of this fieldwork has historically been to illuminate the underwater world and three generations of dolphins in this area, in 1997 we piloted a two-way communication system between humans and dolphins.

4. Framework for two-way work

Initial and required conditions for our two-way work with these dolphins included: (1) locating an area where it was possible for researchers to work in the water safely and observe dolphins underwater, (2) having the mutual interest and voluntary participation by a culturally stable and gregarious species, (3) having baseline knowledge about the society and the individuals, (4) establishing trust and long-term relationship with individuals, (5) using non-invasive techniques and approaches, (6) having the ability to commit a minimum of 20 years for generational tracking, (7) strictly adhering to etiquette and respectful relationship at all times, (8) having a consistent and trained human team, (9) having dedicated time to work, (10) making the system accessible and interesting, (11) utilizing interactive windows that were not disrupted to the species natural behavior, (12) assuming adequate cognitive abilities of the dolphins and their mutual interest and participation, and (13) utilizing an exposure, vs. training protocol that encouraged and allowed access to communication tools for all participants in the water.

The technical design and implementation of the two-way human/dolphin system is described in detailed elsewhere [28]. The system was essentially an underwater keyboard that labeled objects, actions, and locations, for dolphin access with a visual as well as acoustic signal. The acoustic design included frequency modulated whistles that were outside the normal dolphin repertoire of whistles but within their abilities to mimic. Visual symbols were white on a black background to enhance contrast.

Humans modeled the use of this keyboard communication system during play and social time with the dolphins. Preliminary results show that (1) dolphins attended to human demonstration communication of system after exposure to tones, system/methodology pointing and attention, (2) individual dolphin candidates emerged and all dolphins were juvenile females, and (3) the spotted dolphins used the system including recruiting of bottlenose dolphins during sessions.

The biggest predictor of successful sessions was whether humans and dolphins synchronized their swims and had eye contact before a session. A slow pace of interaction and spontaneous mimicry were also good predictors. Dolphins are master postural [29] as well as acoustic mimics [30] and also used coordinated actions in their own society [31,32].

Relative to the concerns of SETI, bridging the gap between two sentient species may have the following requirements:

(1) Access to another species that has mutual interest and the ability to participate, within their own culture/age class structure, with humans. Humans will need to develop measures of awareness/intention of communication that might include eye gaze, synchrony, mimicry, and other prosodic features of communication. Humans need to look for windows of opportunity and be prepared and practiced.
(2) Appropriate frameworks would include a knowledge base about the species/society, ethics, their etiquette and rules. Such work would take specific methods, technology, technique, tools, and personnel. It would likely take the form of participatory science (an interactive, anthropologic framework), while staying sensitive to enculturation issues to insure the retention of species identity while attempting to bridge the gap.
(3) Sensory system bridges would be critical to determine where two species can meet and communicate. Technology would likely be involved and include cross-modal issues, and potential synesthetic features, metasignals, universals or emergent features as keys to communication.
(4) Dynamic feedback and flexibility would be critical for real-time adjustments in methods, use of emergent properties, and real time recognition of individuals, personalities, and ambassadors. Potential impact would need to be monitored to minimize enculturation issues and harm to the society.
(5) If contact is real-time but still at a distance, modification of the above dynamics, adapting for remote yet real-time interaction, should be considered.

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